



Green Aviation: A Better Way to Treat the Planet

People around the world are taking to the skies in increasing numbers. In 2009, for the first time ever, Asia hosted more air travelers than North America, while carriers in the United States flew 704 million passengers, a number forecast to reach 1.21 billion by 2030.

Accommodating such growth will require new aircraft and more flights, plus new runways and airports. Without intervention, the likely consequences are a significant escalation in harmful jet engine emissions, unprecedented traffic jams in the sky, nonstop noise near airports, and more citizens unhappy about the effects on their health and their quality of life.

In order to eliminate as much potential harm to the environment as possible and make air travel as efficient and economical as it can be, NASA is working closely with its government, industry and university partners on a number of environmentally beneficial, or "green," aviation initiatives.

Spread across NASA's existing portfolio of aeronautical research, green aviation is not considered part of a single project or program. Green aviation represents an aim that has guided many of NASA's research goals since the earliest days of aviation, and especially after the environmental awareness and the energy shortages of the 1970s required inventing innovative ways to quiet airplanes, reduce air pollution and burn fuel more efficiently.

In addition to aircraft-related improvements, green aviation touches on air traffic management, which focuses mostly on enabling aircraft to move more efficiently through the national airspace system, thus reducing noise, emissions and fuel burn.

A greener future for aviation holds the promise of new life for airports, because people will be able to enjoy the convenience and commercial benefits of living near an airport without enduring the racket and fumes that are so aggravating today.



NASA's goal is to reduce aircraft fuel consumption, emissions and noise simultaneously. *Image credit: NASA*

NASAfacts

Goals for Green Aviation

NASA has a set of research goals that can be described as “green” because they relate to mitigating environmental impacts of aviation. NASA’s goal is to reduce aircraft fuel consumption, emissions and noise simultaneously, which is a much more difficult challenge than working to reduce them individually.

Fuel Efficiency

The challenge: In 2008, major U.S. commercial air carriers burned 19.7 billion gallons of jet fuel, while aircraft owned and operated by the Department of Defense consumed another 4.6 billion gallons of jet fuel. At an average price of \$3 per gallon, the total cost of fuel was \$73 billion.

The goal: Develop aircraft technology capable of reducing fuel burn significantly. This technology should enable the design of new aircraft that burn 33 percent less fuel than today’s airplanes by 2015, 50 percent less by 2020 and at least 70 percent less by 2025. It also should enable the adoption of new air traffic management operations that save up to 6 percent of annual commercial aviation fuel consumption by 2035.¹

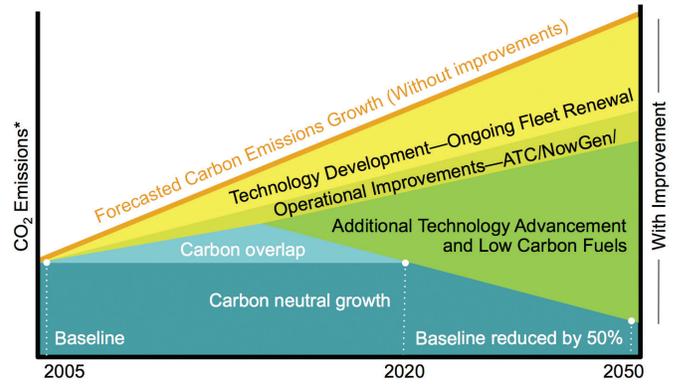
Emissions

The challenge: Fuel consumed by the U.S. commercial air carriers and the military releases more than 250 million tons of carbon dioxide (CO₂) into the atmosphere each year. CO₂ is a greenhouse gas and a contributor to global warming. Other major emissions are nitric oxide (NO) and nitrogen oxide (NO₂), which together are called NO_x and contribute to ozone creation; sulfur oxides (SO₂); and particulates (often referred to as soot). Forty of the top 50 U.S. airports are in areas that do not meet Environmental Protection Agency local air quality standards for particulate matter and ozone. Reducing NO_x emissions also reduces SO_x emissions. Reducing the amount of fuel burned reduces CO₂ emissions.

The goal: Develop aircraft technology and air traffic management capable of cutting NO_x emissions 20 percent by 2015 when compared with today’s best engines, 50 percent by 2020 and greater than 50 percent by 2025, and transfer the technology to industry.²

¹ The reference aircraft for the NASA’s fuel efficiency goal is a 300-passenger, long-range transport with GE 90 engines, manufactured in 1997 or 1998. The goal dates represent a technology readiness level of 6, which is considered ready for flight testing. This is the point at which NASA traditionally transfers a new technology to industry for further development toward operational readiness and certification by governing authorities such as the Federal Aviation Administration.

² NASA’s emissions reduction goals are based on a standard known as International Civil Aviation Organization’s Committee on Aviation Environmental Protection Sixth Meeting, or CAEP/6. Most aircraft engines in use today meet or exceed CAEP6. Related to this standard, NASA’s goals are to create technology capable of enabling engines that emit 60 percent less NO_x, by 2015, 75 percent less by 2020, and greater than 75 percent less by 2025. The goal dates represent a technology readiness level of 6, which is considered ready for flight testing. This is the point at which NASA traditionally transfers a new technology to industry for further development toward operational readiness and certification by governing authorities such as the Federal Aviation Administration.

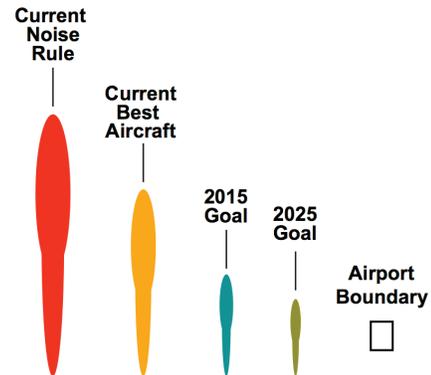


This graphic illustrates that, with no improvements, carbon emissions grow dramatically through 2050. With technology developments, operational improvements, additional technology advancement and low carbon fuels, carbon neutral growth could actually be achieved by the year 2020 and, by 2050, a baseline reduction of 50 percent. Source: Federal Aviation Administration. Adapted with permission.

Noise

The challenge: Aircraft noise continues to be regarded as the most significant hindrance to increasing the capacity of the National Airspace System, largely because of nuisance noise near major metropolitan airports. Although the Federal Aviation Administration has invested more than \$5 billion in airport noise reduction programs since 1980, the problem persists.

The goal: Develop aircraft technology and airspace system operations to shrink the nuisance noise footprint around each airport until it is about one-third of its current size by 2015, about one-sixth its size by 2020, and contained within the airport property boundaries by 2025.³



Looking to the future, the ultimate goal is to confine any objectionable noise within the boundaries of an airport. Source: NASA

³ NASA’s noise reduction goals are related to current Federal Aviation Administration standards for aircraft in service today. NASA’s goals are to create technology that can enable a 32dB reduction in noise by 2015, a 42dB reduction by 2020, and a 71dB reduction by 2025. The goals relate to Stage 4 of those standards, whose acceptable noise limits within specific geographic boundaries vary by an aircraft’s size, weight and number of engines. The limits are sum of three acoustic measurements taken as the aircraft takes off and climbs, and approaches and lands. The goal dates represent a technology readiness level of 6, which is considered ready for flight testing. This is the point at which NASA traditionally transfers a new technology to industry for further development toward operational readiness and certification by governing authorities such as the Federal Aviation Administration.

Solutions for Green Aviation

NASA is working on ideas to deal with the environmental issues of fuel burn, emissions and noise. Some ideas have to do with improvements in technology; others have to do with using new technology in new ways.

Here are some examples:

- Changes in the way an airliner's transit through the nation's air traffic control system is managed, by allowing pilots to take off and climb directly to their cruising altitude or descend directly to touchdown, without leveling off periodically to check in with air traffic control along the way.

Data from the top 27 airports in the U.S. indicate this operational improvement could reduce the amount of fuel burned each year by 188 million gallons with direct climbs, and 218 million with continuous descents. Similarly, by integrating new satellite-based air traffic information and communication systems into existing cockpit instrumentation and displays, new procedures for managing the flow of air traffic may allow airliners to fly more efficient, direct routes to their destinations. This could save 200 million gallons of fuel each year.

- Changes in aircraft design, such as the use of lightweight composite structures and means to increase laminar, or smooth, air flow over aircraft surfaces, can increase overall lift and reduce drag.

These improvements require less engine power for an aircraft to fly at the same speed and altitude, and thus represent important contributions to achieving the goal of reducing fuel burn rates by as much as 50 percent over current rates. An example of a "green" design change can be seen in the blended wing and body of the subscale, flying X-48B aircraft prototype.



Future aircraft designs that generate dramatic reductions in noise, emissions and fuel consumption could look like this hybrid wing body. *Image credit: NASA*

- Changes in engine design or operation might include ultra-high bypass turbofans, open rotor engines, use of alternative fuels or locating engines on the body of the aircraft in such a way that deflects engine noise upward to keep it from reaching the ground.

Other concepts may include capitalizing on the potential of advanced electrical power technologies such as batteries or fuel cells to reduce the amount of fuel needed.

Green Aviation Research Begins with Fundamentals

NASA's green aviation research takes place at all four of the agency's aeronautical field centers, including the Ames Research Center at Moffett Field, Calif., Dryden Flight Research Center at Edwards Air Force Base, Calif., Glenn Research Center in Cleveland, and Langley Research Center in Hampton, Va.



Advanced technologies that help make aircraft more environmentally friendly are first likely to show up on tube-and-wing aircraft. *Image credit: NASA*

The work is managed by the Aeronautics Research Mission Directorate at NASA Headquarters in Washington, which is organized into five programs that oversee a number of projects.

The programs are the Fundamental Aeronautics Program, Airspace Systems Program, Aviation Safety Program, Aeronautics Test Program, and the recently added Integrated Systems Research Program.

Research into green aviation technology begins at an elementary level in the laboratory. For example, a new air traffic management or aircraft vehicle concept is first identified and matured within the Airspace Systems Program or Fundamental Aeronautics Program. The overarching goal of the Fundamental Aeronautics Program is to achieve technological capabilities necessary to overcome national challenges in air transportation including reduced noise, emissions and fuel consumption, and increased mobility through a faster means of transportation. The Airspace Systems Program is responsible for developing concepts, capabilities, and technologies for high-capacity, efficient, and safe airspace and air portal systems.

Should a particular concept or technology demonstrate potential for success, it may be matured further within the Integrated Systems Research Program, where research is designed to test more mature concepts with others as a system in real-world environments. This higher level research is clustered in the Environmentally Responsible Aviation Project, which is part of the Integrated Systems Research Program.



Wind tunnels, simulators and other testing facilities help answer key, early questions about the promise of technology options. *Image credit: NASA*

Within the Environmentally Responsible Aviation Project, research toward achieving the simultaneous goals described earlier is organized into three main areas:

1. **Airframe Technology:** Addresses areas such as lightweight structures, flight dynamics and control, and drag, all with the goals of reducing noise and fuel burn.
2. **Propulsion Technology:** Focuses primarily on high-pressure engine-core components and propulsion technologies, with the goals of lowering harmful emissions and fuel burn.
3. **Vehicle Systems Integration:** Addresses the integration of airframe and propulsion technologies, including vehicles configured to shield engine noise with the airframe.

Safety is the Top Priority

NASA's goals are to expand aviation system capacity, enable fuel-efficient flight planning, reduce the overall environmental footprint of airplanes today and in the future, reduce delays on the ground and in the sky, and improve the ability to operate in all weather conditions while maintaining the current high safety standards everyone demands.

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